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# Storage Behavior of LEMONS From the Desert Areas of Arizona and California

Marketing Research Division
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**Rygg, George Leonard,** 1903–

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# STORAGE BEHAVIOR OF LEMONS FROM THE DESERT AREAS OF ARIZONA AND CALIFORNIA

By G. L. Rygg and E. M. Harvey, senior plant physiologists
Biological Sciences Branch, Marketing Research Division
Agricultural Marketing Service[1]

## SUMMARY

Lemons from three desert areas in Arizona and California were stored at 58° to 60° F. and 89 to 91 percent relative humidity. Various observations and measurements were made before storage and at monthly intervals up to 7 months' storage.

The lemons lost weight at rates of 2 to 3 percent per month. Villafranca lemons lost weight somewhat less rapidly than the Eureka and Lisbon varieties. Four maturities of Eureka lemons lost weight at about equal rates.

Decay was low in all lots of dark green lemons, but Villafranca lemons from trees on rough lemon rootstock decayed considerably more than those in any other lot. More than 7 percent of the tree-ripe Eureka lemons decayed in 2 months. The percentage of decay in the other maturities was related to maturity, but the percentages were far below that of the tree-ripe fruit.

Darkening of the button color was erratic and was not closely related to fruit decay.

Rind color changed from green to pale green or yellow in 1 month. Some fruits had a green tint after 2 months, but most had turned yellow. Most fruits were bright lemon yellow after 3 months, but some bronzing was noticeable. Bronzing became prominent after 4 to 5 months.

Loss of firmness began to be noticeable after storage extended beyond 3 months. Softening and bronzing are likely to limit the commercial storage life of these lemons.

All the lemons had a high juice content, the volume of the juice ranging from 40 to 45 percent of the volume of the fruit at harvest and from 45 to 50 percent after 1 to 2 months' storage. This is equivalent to 877 to 969 pounds per ton at harvest and 893 to 1,027 pounds after 1 to 2 months' storage. Degree of maturity at harvest did not affect juice yield consistently.

Acid concentration decreased slowly throughout storage except for the first month in Eureka and Lisbon varieties. The yield of acid in pounds per ton of fruit increased during the first month's storage because of the increased yield of juice with a nearly constant acid concentration. Both the concentration and the yield in pounds per ton were lower in tree-ripe lemons than in less mature ones. The other maturities gave about equal yields.

Ascorbic acid concentration, based on the initial weight of the fruit, remained nearly constant throughout storage, and the three varieties were about equally rich in this vitamin. The concentration in small immature Lisbon lemons was considerably higher than that in the larger, more mature ones. The four maturities of Eureka lemons contained about equal concentrations.

The rind, which constituted an average of 45.6 to 48.5 percent of the weight of the three varieties at harvest, decreased to 39.8 to 43.5 percent after 1 month's storage; subsequent decreases were small. The percentage of rind was lowest in the tree-ripe fruit at harvest, but no difference related to maturity remained after 1 month's storage.

[1] Dr. Harvey retired in March 1958.

## INTRODUCTION

Recent sizable increases in plantings of lemons in the desert areas of Arizona and California call for specific information on the storage potential and other characteristics of lemons grown in this environment. Both experimental and commercial experiences show that distinct differences occur in other kinds of citrus fruits grown on the coastal side of the main north-south mountain ranges of California and those grown on the desert areas east of these mountains.

This study of the storage behavior of lemons is part of a broad program of continuing research designed to improve the marketing of farm products. The lemons were provided by Yuma Citrus Co., Spry Ranch, Yuma Mesa Fruit Growers Association, and Coastal Luck, of Yuma, Ariz.; Mehren Ranch, Bodine Ranch, and Arrowhead Ranch, Inc., of Phoenix, Ariz., and surrounding territory; and the W-N Ranch of Thermal, Calif. The Arlington Heights Citrus Co., of Arlington, Calif., provided storage for all the lemons.

## MATERIALS AND METHODS

Lemons were obtained from 4 groves each of the Eureka and Lisbon varieties, 2 of each near Yuma, Ariz., 1 of each near Phoenix, Ariz., and 1 of each in the Coachella Valley, Calif. Lemons of the Villafranca variety were obtained from 2 groves in the vicinity of Phoenix. The trees in one of the groves of Villafranca lemons were grafted on sour orange rootstock and the other on rough lemon. All the lemons from the Coachella Valley grew on trees grafted on rough lemon rootstock. The identity of the other rootstock was not known with certainty.

The first picking consisted of eight boxes of dark to light green maturity from each grove. The second picking was limited to the Eureka variety in the Coachella Valley. This picking consisted of four maturities: Dark green, light green, silver, and tree ripe. The lemons from the Yuma area were picked on September 21, 1957, and those from the Phoenix area on October 17 and 18. The first picking in the Coachella Valley was made on October 16 and the second on December 11, 1957.

All the lemons were washed, waxed, and stored at a commercial lemon packinghouse at Arlington, Calif. The wash water, which contained sodium orthophenylphenate, was applied at 90° F. The fruit was dipped in 1-percent water wax containing 500 p.p.m. of 2,4-D and was stored at 58° to 60° and 89 to 91 percent relative humidity for as long as 7 months.

One box of lemons from each lot was examined immediately after the packinghouse treatments were completed. Subsequently, 1-box units were examined at monthly intervals. Each box from 9 of the 10 groves used in the first picking contained approximately 175 lemons, but the fruit from one of the Lisbon groves was small and immature, and a box contained about 350 lemons. Each box in the second picking contained about 190 lemons.

The lemons were examined for weight loss, decay, button and rind color, and firmness. They were weighed and measured for volume by water displacement and then cut and reamed on an electric reamer equipped with a vibrating strainer. The portion that passed through the vibrating strainer was strained again by passing it through a double thickness of cheesecloth under hand pressure, and the juice content, total acid, ascorbic acid, and proportion of rind were measured. Both the volume and the weight of the juice were obtained.

Decay is reported for the entire 7-month storage period, but most of the other data cover only 6 months. Juice is reported as a percentage of the volume of the fruit and by pounds per ton of fruit; total acid, as the percent of anhydrous citric acid in the juice and as pounds per ton of fruit; and ascorbic acid, as milligrams per 100 milliliters of juice, all adjusted to the size and weight of the fruit at harvest. Ascorbic acid was measured by the usual 2,4-dichlorophenolindophenol titration.

## RESULTS

Loss of weight. --The lemons lost weight at a fairly uniform rate of approximately 2 percent per month during the entire storage period of 7 months. Eureka and Lisbon lemons lost weight at about equal rates, but the rate for the Villafranca was somewhat lower (table 1).

Table 1.--Loss of weight of lemons, expressed as percentage of initial fresh weight, after 1 to 6 months in storage, by variety and maturity

| Item | Months in storage | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Variety: | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Eureka[1] | 2.9 | 5.6 | 7.0 | 8.5 | 9.6 | 12.1 |
| Lisbon[1] | 2.1 | 5.0 | 6.7 | 8.0 | 9.9 | 12.2 |
| Villafranca[2] | 2.1 | 3.5 | 5.2 | 6.0 | 7.1 | 10.6 |
| Maturity:[3] | | | | | | |
| Dark green | 3.7 | 6.4 | 7.6 | 9.2 | --- | 19.1 |
| Light green | 4.7 | 6.2 | 8.0 | 10.8 | --- | 20.0 |
| Silver | 4.3 | 6.6 | 8.5 | 10.3 | --- | --- |
| Tree ripe | 3.6 | 5.5 | --- | --- | --- | --- |

[1] Averages of 4 lots of each variety.
[2] Averages of 2 lots.
[3] Each value is the average of about 190 Eureka lemons.

Eureka lemons of 4 different maturities lost weight at about equal rates of 2 to 3 percent per month (table 1). The lemons used for a comparison of maturities were picked about 2 months later than those used for a comparison of varieties. They lost weight somewhat faster than those harvested earlier.

Decay. --Very few lemons decayed during the experiment. Table 2 presents average percentages of decay in four lots each of Eureka and Lisbon lemons. During the first 5 months of storage, decay exceeded 1 percent in only 2 of the boxes of lemons examined, and 31 of the 40 boxes examined contained no decayed fruit. The decay in all the lots of these two varieties was fairly uniform.

The two lots of Villafranca lemons differed materially from each other in the amount of decay and are therefore listed separately in table 2. Decay in lemons from Villafranca trees on sour orange rootstock (lot 7) was no greater than in the Eureka and Lisbon varieties. On the other hand, much more decay developed on lemons from Villafranca trees on rough lemon rootstock (lot 8) than on those from any other grove. This difference is apparent in the following tabulation, which shows the average decay in each lot of lemons during the entire storage period:

| Lot No. and variety | Decay Percent | Lot No. and variety | Decay Percent |
|---|---|---|---|
| 1 Eureka | 0.3 | 7 Villafranca | 0.2 |
| 2 Lisbon | .9 | 8 Villafranca | 1.9 |
| 3 Eureka | .2 | 9 Lisbon | .4 |
| 4 Lisbon | .5 | 10 Eureka | .1 |
| 5 Eureka | .4 | 11 Eureka | .1 |
| 6 Lisbon | .4 | | |

Twice as many lemons decayed in lot 8 as in the next worst lot (lot 2), and 19 times as many as in the best lots (10 and 11). The difference in tendency to decay observed in this experiment should be investigated further.

Amount of decay did not increase with advanced harvest maturity up to and including silvers until the lemons had been in storage more than 3 months. The decay incidence at the end of 4 months' storage was in the order of maturity, with the more mature fruit showing more decay (table 2).

Table 2.--Decay of lemons after 1 to 7 months in storage, by variety and maturity

| Item | Months in storage | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Variety and root-stock: | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Eureka[1]..... | 0 | 0 | 0.3 | 0 | 0.4 | 0.4 | 0.7 |
| Lisbon[1]..... | 0.1 | 0 | .8 | 0 | .1 | 1.4 | 1.3 |
| Villafranca on sour orange[2]... | .5 | 0.5 | 0 | 0 | .5 | 0 | 0 |
| Villafranca on rough lemon[2]... | 1.3 | .7 | 2.0 | 2.6 | 1.2 | 3.3 | 2.1 |
| Maturity:[3] | | | | | | | |
| Dark green..... | 0 | 0 | 0 | 0.5 | 0 | 0.5 | 0 |
| Light green..... | 0 | 0 | 0.5 | 1.1 | 0.6 | 0 | 3.0 |
| Silver..... | 0 | 0 | 0 | 2.0 | 1.0 | --- | --- |
| Tree ripe..... | 3.1 | 7.3 | --- | --- | --- | --- | --- |

[1] Averages of 4 lots each.
[2] Lots are tabulated separately.
[3] Each value represents percentage of decay in 1 box of Eureka lemons.

Button color.--Darkening of the button color in lemons from western California is a good indicator of susceptibility to decay, according to a previous study.[2] This relationship was not observed in the desert-grown lemons used in this experiment; at least no such relationship was found up to the end of 7 months' storage. By that time the fruit was long past commercial salability because of softening and bronzing. The lack of uniformity in maturity within the lots probably contributed to the lack of relationship between button color and condition of the lemons, but the low incidence of decay prevented the establishment of a button color-to-decay relationship. Furthermore, the application of 2,4-D to lemons is known to delay or inhibit browning and blackening of the buttons. This treatment reduces the relationship between button color and condition of the fruit.

Rind color.--Some green color remained in the rind of the less mature lemons after 1 month's storage, but after 2 months only a faint tint of green remained. A small amount of bronzing developed in the more mature fruit in 3 months, but the deep color did not become prominent until the lemons had been stored 4 to 5 months. Some lemons retained an attractive light yellow color until the end of the experiment.

Firmness.--Desert-grown lemons are often slightly soft at harvest, a condition related to the thin rind and high juice content that characterizes these lemons. Most of the lemons used in these tests remained fairly firm for about 3 months but became noticeably soft thereafter. Loss of firmness and bronzing of the rind color combined to restrict the commercial storage life of these lemons.

[2] Harvey, E. M. Changes in lemons during storage as affected by air circulation and ventilation. U. S. Dept. Agr. Tech. Bul. No. 908, 32 pp. 1946.

Juice content. --All the varieties in this test gave an average juice yield of at least 40 percent at harvest. These values increased about 5 percentage points during the first month or two in storage. The Eureka and Villafranca varieties consistently gave higher juice yields than the Lisbon. Table 3 and figure 1 give these values for storage periods as long as 6 months. The juice content is expressed in both percentage of volume and in pounds per ton of fruit, with all values adjusted to the initial weight and size of the fruit.

Degree of harvest maturity did not influence the yield of juice appreciably (table 3 and fig. 2).

Table 3.--Juice content of lemons before storage and after 1 to 6 months in storage, expressed as percentage of the initial volume of the fruit or as pounds per ton of the initial weight of the fruit, by variety and by maturity

| Item | Months in storage | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Variety: | | | | | | | |
| Percentage of volume:[1] | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Eureka[2] | 45.2 | 49.1 | 49.8 | 49.4 | 51.8 | 52.5 | 51.2 |
| Lisbon[2] | 40.5 | 45.1 | 45.8 | 44.8 | 46.0 | 46.7 | 48.6 |
| Villafranca[3] | 44.8 | 49.1 | 50.2 | 48.8 | 50.1 | 51.4 | 53.3 |
| Pounds per ton of fruit:[1] | *Pounds* | *Pounds* | *Pounds* | *Pounds* | *Pounds* | *Pounds* | *Pounds* |
| Eureka[2] | 969 | 1,014 | 1,004 | 970 | 992 | 999 | 932 |
| Lisbon[2] | 877 | 942 | 918 | 893 | 910 | 897 | 896 |
| Villafranca[3] | 965 | 1,022 | 1,027 | 987 | 994 | 1,016 | 1,006 |
| Maturity:[4] | | | | | | | |
| Percentage of volume:[1] | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Dark green | 47.2 | 48.6 | 49.8 | 51.2 | 51.8 | 55.2 | 55.0 |
| Light green | 50.0 | 48.2 | 52.2 | 53.2 | 52.0 | 54.7 | 55.4 |
| Silver | 47.3 | 47.7 | 50.4 | 52.1 | 48.9 | 53.1 | --- |
| Tree ripe | 50.0 | 47.9 | 51.5 | --- | --- | --- | --- |
| Pounds per ton of fruit:[1] | *Pounds* | *Pounds* | *Pounds* | *Pounds* | *Pounds* | *Pounds* | *Pounds* |
| Dark green | 1,012 | 1,005 | 1,009 | 1,018 | 992 | --- | 935 |
| Light green | 1,082 | 985 | 1,054 | 1,078 | 981 | --- | 934 |
| Silver | 1,018 | 995 | 1,031 | 1,016 | 942 | --- | --- |
| Tree ripe | 1,064 | 995 | 1,062 | --- | --- | --- | --- |

[1] Based on initial weight of fruit.
[2] Average of 4 lots each.
[3] Average of 3 lots each.
[4] Each value represents percent of extracted juice or pounds of juice per ton of fruit from 1 lot of Eureka lemons.

Citric acid. --The concentration of citric acid, when adjusted to the initial weight of the fruit, decreased with increase in storage time in all varieties except for a slight increase in the Eureka after 1 month (table 4). The Villafranca had the highest concentration and the Eureka the lowest throughout the storage period.

The Villafranca gave the highest yield of citric acid expressed in pounds per ton of fruit. The Eureka and Lisbon varieties produced about equal yields. The increase after 1 and 2 months in storage, shown in table 4 and figure 3, is a reflection of the increased extractability of the juice; the acid concentration remained nearly constant. After 1 and 2

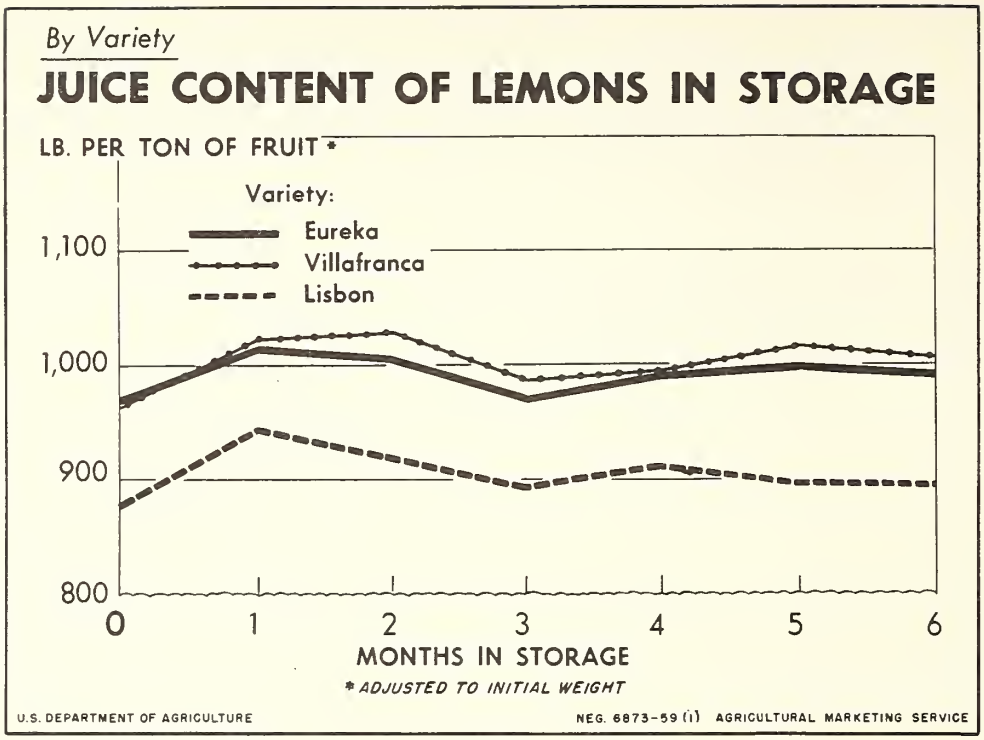


Figure 1

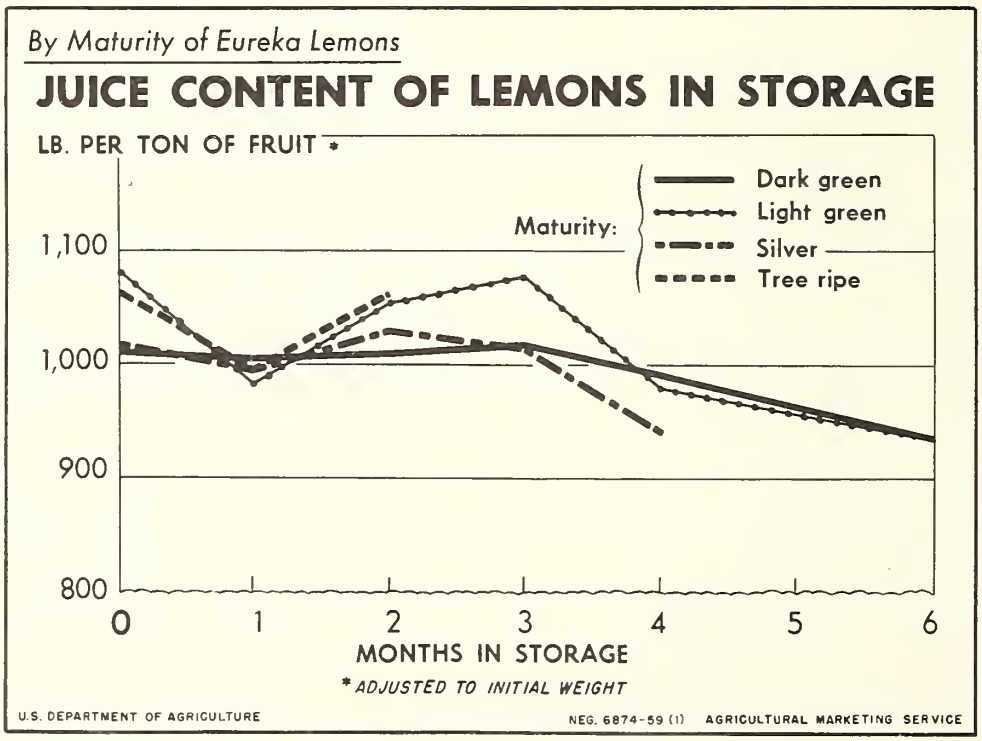


Figure 2

Table 4.--Acid content of lemons before storage and after 1 to 6 months in storage, by variety and by maturity

| Item | Months in storage | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Variety: | | | | | | | |
| Grams of anhydrous citric acid per 100 milliliters of extracted juice:[1] | *Grams* | *Grams* | *Grams* | *Grams* | *Grams* | *Grams* | *Grams* |
| Eureka[2] | 5.90 | 5.95 | 5.81 | 5.49 | 5.30 | 5.15 | 4.92 |
| Lisbon[2] | 6.10 | 6.07 | 5.98 | 5.78 | 5.52 | 5.41 | 5.19 |
| Villafranca[3] | 6.50 | 6.36 | 6.17 | 6.07 | 6.10 | 5.85 | 5.63 |
| Pounds per ton of fruit:[1] | *Pounds* | *Pounds* | *Pounds* | *Pounds* | *Pounds* | *Pounds* | *Pounds* |
| Eureka[2] | 55.0 | 60.0 | 58.9 | 55.2 | 55.4 | 54.3 | 50.4 |
| Lisbon[2] | 51.3 | 58.8 | 57.9 | 55.4 | 54.6 | 54.1 | 53.1 |
| Villafranca[3] | 60.5 | 64.4 | 65.0 | 61.1 | 61.8 | 60.8 | 60.8 |
| Maturity:[4] | | | | | | | |
| Grams of anhydrous citric acid per 100 milliliters of extracted juice:[1] | *Grams* | *Grams* | *Grams* | *Grams* | *Grams* | *Grams* | *Grams* |
| Dark green | 6.00 | 5.97 | 5.90 | 5.82 | 5.72 | --- | 5.10 |
| Light green | 5.90 | 5.91 | 5.91 | 5.80 | 5.62 | --- | 5.04 |
| Silver | 5.90 | 5.93 | 5.79 | 5.67 | 5.47 | --- | --- |
| Tree ripe | 5.40 | 5.49 | 5.48 | --- | --- | --- | --- |
| Pounds per ton of fruit:[1] | *Pounds* | *Pounds* | *Pounds* | *Pounds* | *Pounds* | *Pounds* | *Pounds* |
| Dark green | 58.4 | 60.1 | 60.9 | 61.4 | 60.7 | --- | --- |
| Light green | 60.7 | 58.8 | 63.4 | 63.9 | 59.9 | --- | --- |
| Silver | 58.7 | 59.0 | 61.7 | 60.8 | 55.0 | --- | --- |
| Tree ripe | 55.3 | 54.6 | 59.1 | --- | --- | --- | --- |

[1] Based on initial weight of fruit.
[2] Averages of 4 lots each.
[3] Averages of 3 lots each.
[4] Each value represents grams of anhydrous citric acid per 100 milliliters of extracted juice or pounds per ton of fruit from 1 lot of Eureka lemons.

months' storage the Villafranca lemons from trees on sour orange rootstock gave the highest acid yield, about 67 pounds per ton, and those from one of the Lisbon groves (lot 2) the lowest, about 53 pounds per ton.

Among the four maturities that were compared, the tree-ripe fruit gave the lowest yield of acid in pounds per ton, although the yield of about 55 pounds per ton at harvest was by no means a poor one (table 4 and fig. 4).

Ascorbic acid. --The amount of ascorbic acid in the lemon juice remained nearly constant in relation to the initial weight and size (table 5 and fig. 5). The three varieties were about equally rich in this vitamin. The data for ascorbic acid from the very immature, small-sized fruit of one of the Lisbon groves are shown separately in table 5 and figure 5 to show the high values. The other Lisbon values represent the average of the three remaining Lisbon groves. In presenting the data for the other constituents, the lot of immature fruit is included with the other lots of Lisbon fruit because there were no consistent differences.

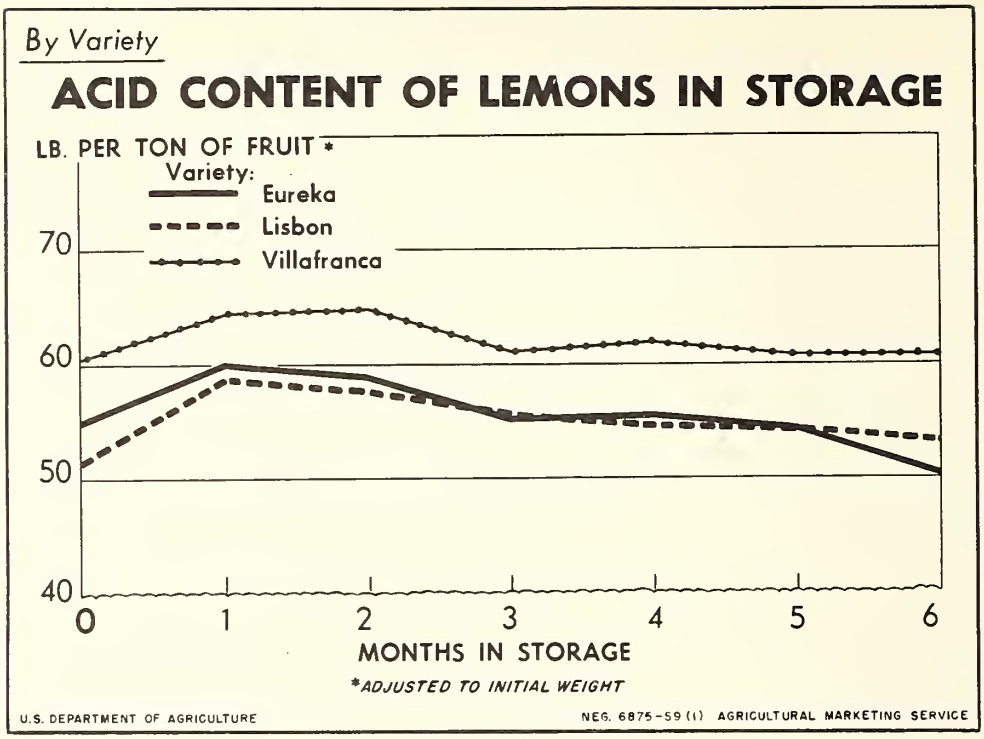


Figure 3

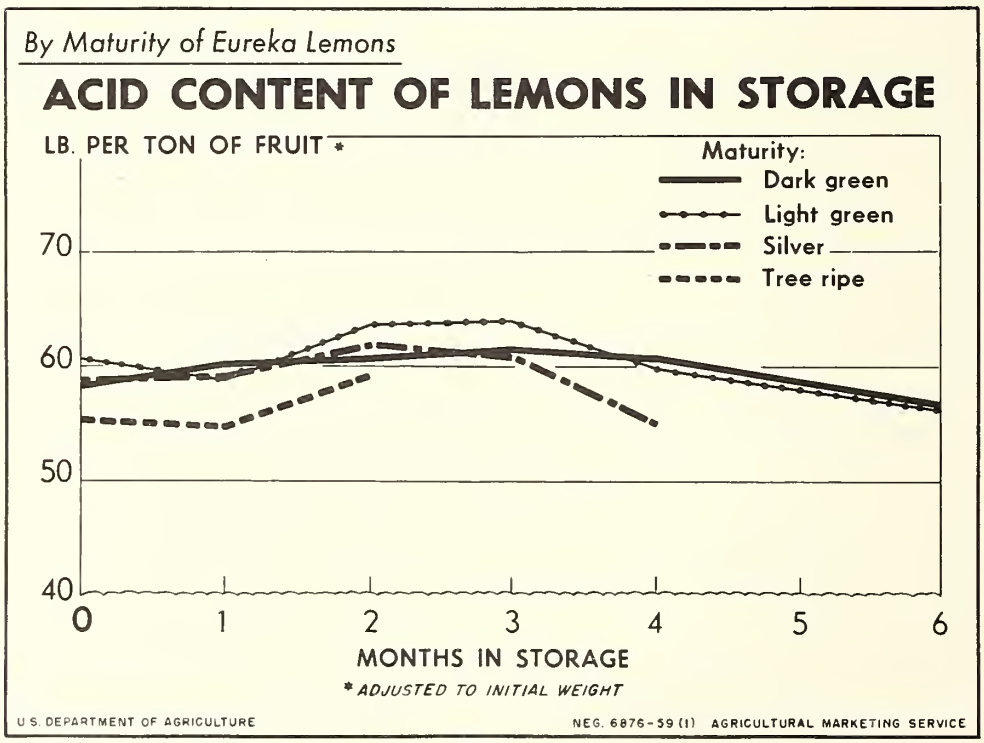


Figure 4

Table 5.--Ascorbic acid content of lemons before storage and after 1 to 6 months in storage, by variety and by maturity

| Item | Months in storage | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Variety: | | | | | | | |
| Milligrams of ascorbic acid per 100 milliliters of extracted juice:[1] | *Mg.* | *Mg.* | *Mg.* | *Mg.* | *Mg.* | *Mg.* | *Mg.* |
| Eureka[2] | 45 | 49 | 48 | 46 | 44 | 45 | 49 |
| Lisbon--commercially mature[3] | 43 | 48 | 42 | 45 | 44 | 44 | 46 |
| Lisbon--immature | 53 | 57 | 57 | 55 | 58 | 60 | 60 |
| Villafranca[4] | 47 | 49 | 43 | 47 | 47 | 49 | 50 |
| Maturity:[5] | | | | | | | |
| Milligrams of ascorbic acid per 100 milliliters of extracted juice:[1] | | | | | | | |
| Dark green | 39 | 40 | 38 | 42 | 44 | --- | 36 |
| Light green | 41 | 40 | 39 | 41 | 43 | --- | 36 |
| Silver | 41 | 41 | 40 | 42 | 45 | --- | --- |
| Tree ripe | 47 | 39 | 41 | --- | --- | --- | --- |

[1] Based on initial weight of fruit.
[2] Average of 4 lots.
[3] Average of 3 lots.
[4] Average of 2 lots.
[5] Each value represents 1 lot of Eureka lemons.

The concentrations of ascorbic acid in the juice from the four maturities from one grove were strikingly similar, both at harvest and after varying lengths of storage (table 5 and fig. 6). The relatively high concentration in the tree-ripe fruit at harvest is the only exception to the uniformity among the maturities. There is no apparent explanation for this unexpectedly high concentration.

Percentage of rind. --The proportion of rind decreased markedly in all varieties during the first month's storage and more slowly thereafter (table 6). The Lisbon contained the highest percentage of rind, and for the first 5 months' storage the Eureka had the lowest.

There was no consistent difference in proportion of rind among lemons of different maturities (table 6).

Table 6.--Proportion of rind in lemons before storage and after 1 to 6 months in storage expressed as percentage of whole fruit, by variety and by maturity[1]

| Item | Months in storage | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Variety: | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Eureka[2] | 45.6 | 39.8 | 39.2 | 38.1 | 35.6 | 34.7 | 35.4 |
| Lisbon[2] | 48.5 | 43.5 | 42.3 | 41.3 | 40.2 | 38.7 | 35.9 |
| Villafranca[3] | 48.0 | 40.8 | 40.4 | 40.5 | 39.3 | 37.0 | 33.9 |
| Maturity:[4] | | | | | | | |
| Dark green | 42.4 | 36.8 | 35.5 | 35.1 | 33.4 | --- | 28.3 |
| Light green | 39.5 | 38.8 | 34.4 | 33.5 | 34.2 | --- | 27.4 |
| Silver | 42.1 | 37.2 | 35.5 | 35.3 | 35.6 | --- | --- |
| Tree ripe | 37.8 | 39.8 | 35.6 | --- | --- | --- | --- |

[1] Based on initial weight of fruit. [2] Average of four lots. [3] Average of two lots.
[4] Each value represents 1 lot of fruit.

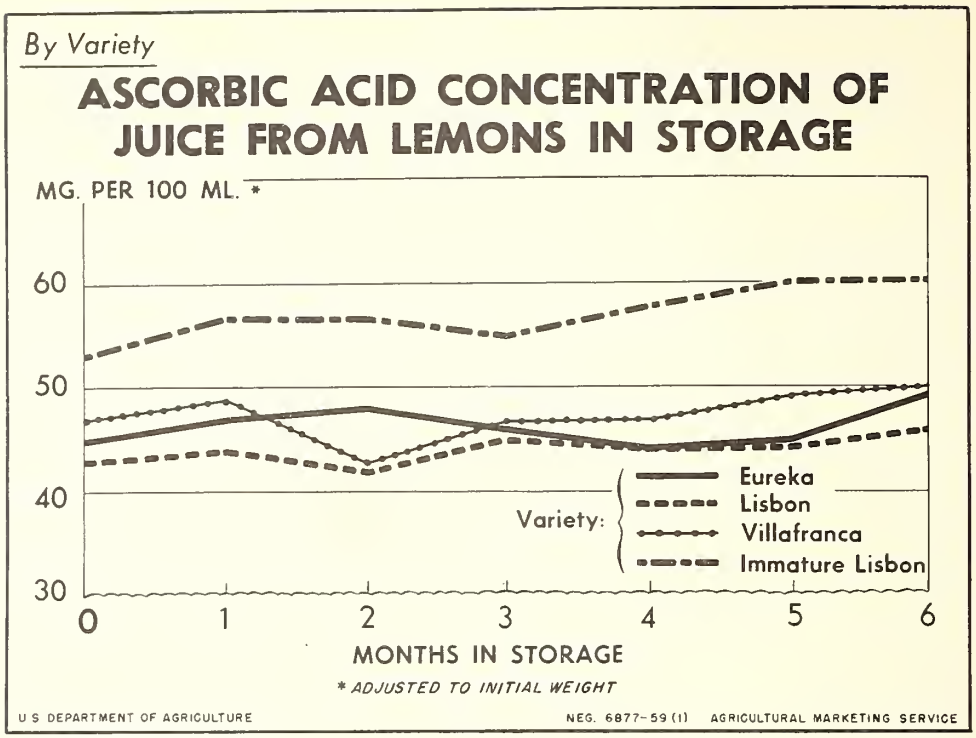


Figure 5

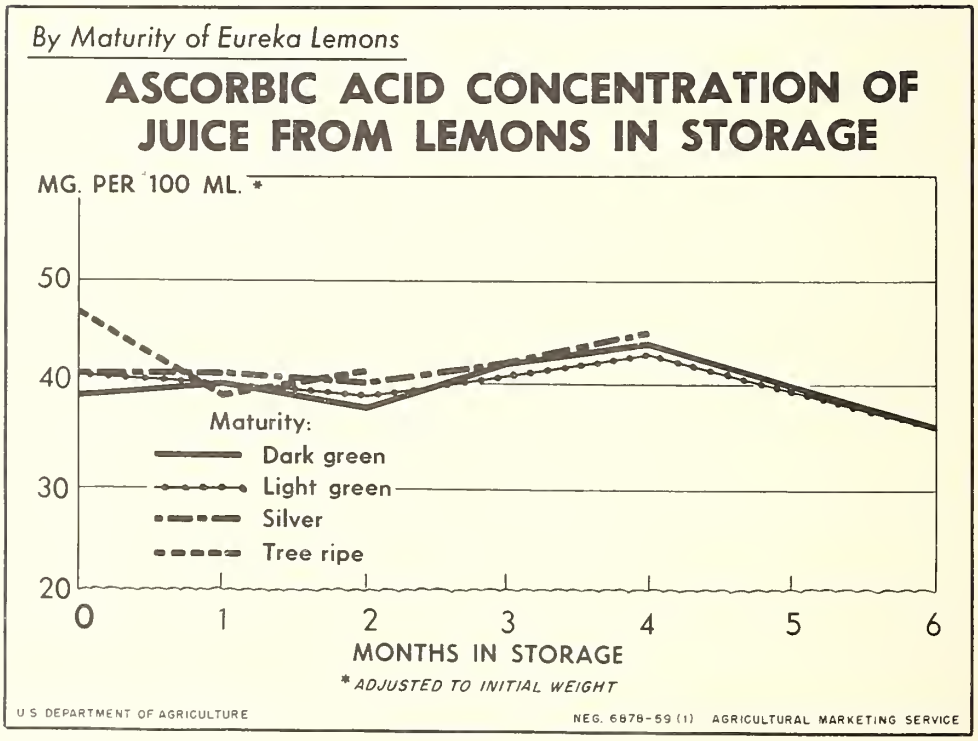


Figure 6



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